Transactions (*continued*).

Munich :—K.B. Akademie der Wissenschaften. Sitzungsberichte (Philos.-Philol.-Histor. Classe). 1891. Heft 4. 8vo. *München* 1892. The Academy.

New York :—American Geographical Society. Bulletin. Vol. XXIII. No. 4. Part 2. Vol. XXIV. No. 1. 8vo. *New York* 1891–92. The Society.

American Museum of Natural History. Bulletin. Vol. III. No. 2. 8vo. *New York* [1892]. The Museum.

Pesth :—K. Ungar. Geologische Anstalt. Jahresbericht. 1890. 8vo. *Budapest* 1892; Foldtani Közlöny. Kötet XXII. Füzet 1–4. 8vo. *Budapest* 1892. The Institute.

Sienna :—R. Accademia dei Fisiocritici. Atti. Ser. 4. Vol. IV. Fasc. 1–2. 8vo. *Siena* 1892. The Academy.

Vienna :—K.K. Geologische Reichsanstalt. Verhandlungen. 1892. No. 2–5. 8vo. *Wien* 1892. The Institute.

Framed copy of Capt. Weir's Azimuth Diagram. Mr. J. D. Potter.

Photographs of the region of Nova Cygni and Nova Aurigæ. Mr. Isaac Roberts, F.R.S.

May 19, 1892.

The LORD KELVIN, D.C.L., LL.D., President, in the Chair.

Dr. George Mercer Dawson (elected 1891) was admitted into the Society.

A List of the Presents received was laid on the table, and thanks ordered for them.

Pursuant to notice, Professor W. Kühne, Professor Éleuthère Élie Nicolas Mascart, Professor Dimitri Ivanovitch Mendeleeff, and Professor Hubert Anson Newton were balloted for and elected Foreign Members of the Society.

The following Papers were read :—

I. "On Nova Aurigæ." By WILLIAM HUGGINS, D.C.L., LL.D., F.R.S., and Mrs. HUGGINS. Received May 16, 1892.

[PLATE 4.]

We had the honour in February last of communicating to the Royal Society a short preliminary note on the remarkable spectrum of this temporary star. We beg now to present a fuller account of our observations, together with two maps of the spectrum of this star, and some theoretical suggestions as to its nature. One map represents the result of our work by eye in the visible region; the other map has been drawn from a photograph of its spectrum, taken without its light having passed through glass, and which extends into the ultra-violet nearly as far as the absorption of our atmosphere permits even the solar rays to pass.

On the Visible Region of the Star's Spectrum.

The kindness of Professor Copeland in sending us a special telegram on February 1 enabled us to commence our observations of the star on February 2, when it was of about the 4·5th magnitude. These observations were continued on the following evening, and on the 5th, 6th, 22nd, and 24th February, and on the 15th, 18th, 19th, 20th, and 24th March, when the sky was more or less sufficiently clear for further observations to be made by eye. On the two ends of the spectrum the observations were usually made with a spectroscope containing one dense prism of 60°, but the comparisons in the brighter parts of the spectrum were observed with a more powerful spectroscope containing two compound prisms.

Comparisons with Hydrogen.—Three bright lines of great brilliancy, about the positions H_α, H_β, and H_γ, left little doubt that they were due to hydrogen. The corresponding lines of a hydrogen vacuum tube were found to fall upon these lines, showing that they had their origin in this gas; but the line in the star at F, which could be best observed, showed a large shift of position towards the red. The line from the vacuum tube fell not upon the middle of the line, but near its more refrangible edge. The star line was brighter on the more refrangible side, so much so, indeed, that our first impression was that this side of the line only might be truly H_β, and the less bright part towards the red, a line of some other substance falling near it. Subsequent observations of the hydrogen lines in the star left no doubt that though they presented the unusual character of being double, and sometimes triple, they were due wholly to hydrogen. These lines were rather broad, but defined, especially so at the more refrangible edge. Similarly to what is observed in

the spectrum of terrestrial hydrogen, C was narrower than F, which again was less broad than H_γ near G.

The remarkable phenomenon presented itself that all the bright hydrogen lines and some other of the bright lines were doubled by a dark line of absorption of the same gas on the blue side. The shift of the dark hydrogen lines towards the blue showed a velocity of approach of this cooler gas somewhat greater than the recession of the gas emitting the bright lines. Our estimates of the relative velocity would place it at about 550 miles a second, which is in good accordance with the result obtained by Professor Vogel from the measurement of his photographs.

So far as our instruments enabled us to determine the point under the unfavourable condition of the rapidly waning light of the star, no great change in the relative motion of the gases producing the bright and dark lines took place from February 2 to about March 7, when the star's light became too faint for such observations—a result which we believe to be in accordance with successive photographs taken at Potsdam, Cambridge (U.S.), Stonyhurst, and some other observatories.

Comparison with Sodium.—A bright line, which on one occasion we glimpsed as double, appeared about the position of D.

Direct comparisons with a sodium flame, while leaving no doubt that the line was due to this substance, showed that it was shifted, similarly to the bright hydrogen lines, towards the red. Perhaps we should state that at the time we had the impression that this line was not shifted to so large an amount relatively to sodium as was the F line relatively to hydrogen. As the comparison was more difficult at this part of the spectrum, and one prism only was used, we do not attach importance to this observation.

Comparisons with Nitrogen and Lead.—There can be little doubt that one of the four brilliant lines in the green is the same line which appeared in the Nova of 1876, and was at that time suspected to be the chief nebular line. Very great pains were taken to ascertain its exact position and character.

For this purpose, on February 2, and again on February 3, direct comparisons were made with the more powerful spectroscope of the star's line with the brightest double line of the nitrogen spectrum, and also with a line of lead, to which line the near relative position of the nebular line is accurately known. Comparisons on both nights, and with both lines, showed that the star line was certainly less refrangible than the chief nebular line, and by a much larger amount than the shift of F relatively to hydrogen. A similar conclusion has been arrived at by Professor Young, Professor Vogel, Dr. Campbell at the Lick Observatory, Father Sidgreaves, Dr. Becker, and M. Bélopolsky at Pulkova. The position of the line in the star

is about λ 5014, and the line may well be one about this position which is frequently seen bright at the Sun's limb.

It may be added that though three faint bright lines are to be seen in the star's spectrum, not far from the place of the second nebular line, no one of them can be regarded as that line. Indeed no certain evidence exists that the chief nebular line occurs without the second line. In some cases of my early observations on the nebulæ in which I recorded the spectrum as consisting of one line only, I have since with better instruments been able to see the second and the third lines as well. The origin of the second, as well as that of the chief nebular line, is not known. Professor Keeler has shown that the second nebular line is not coincident with the double line of iron, which is very near it.

The conclusion that the spectrum of the Nova has no relationship with that of the bright-line nebulæ would be strengthened, if further confirmation were needed, by the absence in a photograph we took of the spectrum of the New Star of a very strong ultra-violet line which is usually found in the spectrum of the nebula of Orion.

Comparison with the Hydrocarbon Flame and Carbon Oxide.—The brightest line in spectrum of the Nova, with the exception of F, falls near the brightest edge of the green fluting of the hydrocarbon flame. Direct comparisons showed the star line to fall a little to the red side of the edge of the fluting; but, allowing for a shift of the star's spectrum, the place of the line would be near, though not coincident with, the brightest edge of the fluting.

The character of the star line leaves, however, no doubt on this point, for it is multiple with the brightest and most defined line on the blue side, contrary to the fluting which is defined on the red side, and gradually falls off towards the blue. If any uncertainty could be supposed still to remain, it was wholly removed when we found no brightenings in the star's spectrum corresponding to the other flutings of the hydrocarbon flame. A bright band in the blue falls just beyond the fluting in this region. This band may have the same origin as a similar band in certain of the Wolf-Rayet stars.

We conclude that the spectrum of the Nova has no relationship with the usual spectrum of comets.

We found from direct comparison that the different set of flutings characteristic of the carbon oxide spectrum was not represented by any corresponding brightenings in the spectrum of the Nova.

Comparison with Magnesium.—It was not unreasonable to suppose that the star line might have its origin in magnesium, the triple line of which at *b* falls almost at the same place. The comparison showed the stellar line to fall upon the more refrangible pair of the magnesium triplet, and to overlap it slightly on both sides, but rather more on the blue side. Considering that with the resolving power

used the three lines of the triplet were well separated, and that we sought in vain for a similar triplet in the star; and, further, that if the probable shift of the star's spectrum towards the red be taken into account, the star line would fall rather more to the blue side of the more refrangible pair of the triplet, we consider it probable that the star line has some other origin. The stellar line is multiple, but it was found difficult to observe it with a sufficiently narrow slit. A thin and defined bright line was clearly seen at the blue side of the rather broad stellar line, but the remaining and less bright part of the line was not certainly made out, but on one occasion it was more than suspected of consisting of several lines.

We consider the evidence to be against the star line having its origin in magnesium, especially as no correspondingly bright lines were observed in the Nova at the positions of the other strong lines of the spark spectrum of magnesium, nor in our photograph at the position of the strong magnesium triplet a little more refrangible than H.

The third bright line in the green of the Nova which is nearest to F, and the least brilliant of the group of lines in this region, was found to have a wave-length of about λ 4921. A large number of bright lines were seen in the spectrum besides those which have been entered on the map (Plate 4).

The lines only of which we were able to fix the position with approximate accuracy are drawn across the spectrum. The places of the lines drawn partly across the map are from estimations only.

We observed a line a little more refrangible than D, of which the position when corrected for the shift of the spectrum, is at or very near that of D_3. Also a bright line below C, and others between C and D.

On February 2 and February 3 groups of numerous bright lines crowded the spectrum between *b* and D, which were less easily seen as the star waned.

The continuous spectrum extended, when the star was brightest, below C, and as far into the blue as the eye could follow it, at this time to a little distance beyond G.

The visible spectrum of the Nova, and especially the reversal of H and K, and of the complete series of the hydrogen lines in the ultra-violet, together with the probable presence of D_3, suggest strongly a state of things not unlike what we find in the erupted matter at the solar surface. In a photograph of a prominence taken on March 4, 1892, which I have received from M. Deslandres, not only H and K and the complete series of hydrogen lines are reversed, but three bright lines appear beyond, which may be more refrangible members of the same series.*

* [M. Deslandres informs me that his measures of the positions of the three lines

Photograph of the Ultra-Violet part of the Spectrum.—On February 22 and March 9 we took photographs of the star with a mirror of speculum metal and a spectroscope of which the optical part is made of Iceland spar and quartz.

The photograph taken on February 22 with an exposure of $1\frac{3}{4}$ hour surprised us in showing an extension of the star spectrum into the ultra-violet, almost as far as the limit imposed upon the light of celestial bodies by the absorption of our atmosphere.

Not only the hydrogen lines near G and at *h*, but also H and K, together with the complete hydrogen series which appears dark in the white stars, came out bright, each with its corresponding absorption line on the blue side. There are some inequalities of brightness in these lines, especially in the line δ, which is brighter than γ or β, which probably arise from lines of other substances falling upon them. On this night K was followed by an absorption, which was less intense than the absorption at H.

Beyond the hydrogen series the spectrum is rich in bright lines, which, in most cases, are accompanied by lines of absorption. Necessarily, from the long range of spectrum included on the plate, the scale is small, and for this reason, and from the faintness of the more refrangible portion of the spectrum when observed under the measuring microscope, the positions given to the stronger groups, which alone have been inserted in the map, must be regarded as approximate only.

Below the spectrum of the Nova, the spectrum of Sirius has been placed for comparison. The group near the more refrangible limit of the spectrum* has been drawn in. Numerous other lines between this group and the end of the hydrogen series have been detected in our photographs of Sirius, but have not yet been measured with sufficient accuracy to justify us in putting them into the map.

In this map no attempt has been made to show the shift of the spectrum of the Nova. The bright lines in the star have been put at the places of the hydrogen lines.

To the extreme limit of the spectrum a faint continuous spectrum shows itself.

The photograph of March 9, exposed for $1\frac{1}{2}$ hour, was rather faint, as the state of the sky was unfavourable.

The apparently Multiple Character of the Lines.—On February 2 we noticed that the F line was not uniform throughout its breadth, and soon came to the conclusion that it was divided, not quite symmetrically, by a very narrow dark line. The more refrangible component was brighter, and rather broader than the other. Later on in Feb-

fall into Balmer's formula for the hydrogen series. We must regard them, doubtless, as members of that series and due to hydrogen.—June 10.]

* 'Roy. Soc. Proc.,' vol. 48, p. 216.

ruary, we were sure that small alterations were taking place in this line, and that the component on the blue side no longer maintained its superiority. We suspected, indeed, at times that the line was triple, and towards the end of February and in the beginning of March we had no longer any doubt that it was occasionally divided into three bright lines by the incoming of two very narrow dark lines.

Similar alterations, giving a more or less apparent multiple character to the lines, are to be seen not only in the bright lines, but also in those of absorption in contemporary photographs taken of the spectrum of the star. I may mention those taken at Potsdam, Stonyhurst, and the Lick Observatory. They were specially watched and measured by M. Bélopolsky at Pulkova.

Professor Pickering informs me that on a photograph taken at Cambridge, U.S., on February 27, H, K, and α are triple, and that Miss Maury recorded, "the dark hydrogen lines rendered double, and sometimes triple, by the appearance of fine bright threads superposed upon the dark bands."

To explain these appearances on the assumption that each component of the bright and dark lines is produced by the emission or absorption of hydrogen moving with a different velocity would require a complex system of six bodies all moving differently.

A much more reasonable explanation presents itself in the phenomena of reversal, which are very common on the erupted solar surface and in the laboratory.*

Professor Liveing informs me that he and Professor Dewar, in their researches with the arc-crucible, met with cases in which, through the unequal expansion of the bright line on the two sides, the narrow reversed dark line did not fall upon the middle of the broader bright line, but divided it unsymmetrically. This effect was notably shown in photographs which they took of the spectrum of zinc. Unsymmetrical division of the lines by reversal would also come in, if the cooler and hotter portions of the gas were possessed of relative motion in the line of sight.

* [M. Deslandres permits me to quote the results of his recent observations on this point:—"Lorsque l'on dirige sur la fente d'un spectroscope de grande dispersion l'image d'une facule du soleil on a invariablement avec les raies H et K du calcium un renversement triple. Même lorsque les facules sont larges et intenses, on obtient encore le renversement triple avec des raies brillantes centrales, plus faibles il est vrai, si l'on envoie dans le spectroscope la lumière de tous les points du soleil, comme c'est le cas pour les étoiles; par exemple en dirigeant le collimateur vers le soleil sans l'intermédiaire d'aucun objectif, ou encore en le dirigeant vers un point quelconque du ciel. Si les facules sont au centre la raie centrale est à sa place normale, si elles sont à l'est ou à l'ouest la raie centrale est déplacée légèrement (2 kil. au plus) mais déplacée sûrement. Au point de vue pratique cette propriété fournit un moyen de reconnaître l'état général de la surface solaire lorsque le soleil est caché par les nuages."—June 20.]

These observers met also with double reversals, which gave a triple character to the expanded single line. In one experiment, when sodium carbonate was introduced into the arc the reversed D lines were seen as a broad dark band with a bright diffuse band in the middle. As the sodium evaporated the band narrowed, and the bright line in the middle showed a second reversal within it. This was a case of threefold reversal.

There would seem to be little doubt but that the more or less divided character—sometimes unsymmetrically—of the bright and dark lines of the Nova, which appeared to be undergoing continual alterations, was due to the incoming upon the broader lines of narrow reversed lines, bright or dark, as the case might be. Provision must therefore be made for conditions favourable for such reversals in any hypothesis which is suggested to account for the phenomena of the new star.

Waning of the Star.—The first record of this star was its appearance as a star of the 5th magnitude on a plate taken at Cambridge, U.S., on December 10, 1891. No star so bright as the 9th magnitude was found at its place on a plate taken by Dr. Max Wolf on December 8. Combining the photographic magnitudes obtained at Greenwich with the visual ones made at the University Observatory, Oxford, and by Mr. Stone and Mr. Knott, we find that throughout February and the first few days of March the light of the star declined very slowly, but with continual and considerable fluctuations, from about the 4·5th magnitude down to the 6th magnitude. After March 7, the remarkable swayings to and fro of the intensity of the light, set up probably by commotions attendant on the cause of its outburst, calmed down, and the star fell rapidly and with regularity to about the 11th magnitude by March 24, and then down to about 14·4th magnitude by April 1. On April 26, however, it was still visible at Harvard Observatory, magnitude 14·5, on the scale of the meridian photometer.

We observed its spectrum for the last time on March 24, when it had fallen to nearly the 11th magnitude. We were still able to glimpse the chief features of its spectrum. The four bright lines in the green were distinctly seen, and appeared to retain their relative brightness; F the brightest, then the line near b, followed by the lines about λ 5015 and λ 4921.

Traces of the continuous spectrum were still to be seen. Considering the much greater faintness of the continuous spectrum when the star was bright on February 2 than the brilliant lines falling upon it, we are not prepared to say that the falling off of the continuous spectrum was greater than might well be due to the waning of the star's light.

Professor Pickering informs me that on his plates "the principal bright lines faded in the order K, H, α, F, h, and G, the latter line

becoming much the brightest when the star was faint." The calcium lines K and H showed signs of variation during the whole time of the star's visibility, and I may remark that the order of the other lines agrees with the relative sensitiveness of the gelatine plate for these parts of the spectrum. Professor Pickering's photographic results appear to us to be in accordance with those we arrived at by eye, in not showing any material alteration in the nature of the star's light, notwithstanding its very large fall of intensity.

General Conclusions.

Among the principal conditions which must be met by any theory put forward to account for the remarkable phenomena of the new star stands the persistence without any great alteration—though probably with small changes—of the large relative velocity of about 550 miles a second in the line of sight between the hydrogen which emitted the bright lines and the cooler hydrogen producing the dark lines of absorption.

If we assume two gaseous bodies, or bodies with gaseous atmospheres, moving away from each other after a near approach, in parabolic or hyperbolic orbits, with our Sun nearly in the axis of the orbits, the components of the motions of the two bodies in the line of sight, after they had swung round, might well be as rapid as those observed in the new star, and might continue for as long a time without any great change of relative velocity. Unfortunately information as to the motions of the bodies at the critical time is wanting, for the event through which the star became suddenly bright had been over for some forty days before any observations were made with the spectroscope.

Analogy from the variable stars of long period would suggest the view that the near approach of the two bodies may have been of the nature of a periodical disturbance, arising at long intervals in a complex system of bodies. Chandler has recently shown in the case of Algol that the minor irregularities in the variation of its light are probably caused by the presence of one or more bodies in the system. besides the bright star and the dusky one which partially eclipses it. To a similar cause are probably due the minor irregularities which form so prominent a feature in the waxing and waning of the variable stars as a class. We know, too, that the stellar orbits are usually very eccentric. In the case of γ Virginis the eccentricity is as great as 0·9, and Auwers has recently found the very considerable eccentricity of 0·63 for Sirius.

The great relative velocity of the component stars of the Nova, however, seems to point rather to the casual near approach of bodies possessing previously considerable motion; unless we are willing to

concede to them a mass very great as compared with that of the Sun. Such a near approach of two bodies of great size is very greatly less improbable than would be their actual collision. The phenomena of the new star, indeed, scarcely permit us to suppose even a partial collision; though if the bodies were very diffuse, or the approach close enough, there may have been possibly some mutual interpenetration and mingling of the rarer gases near their boundaries.

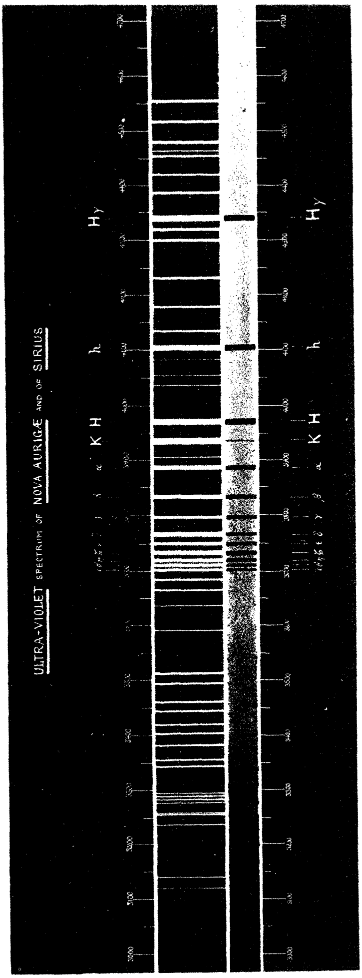
A more reasonable explanation of the phenomena, however, may be found in a view put forward many years ago by Klinkerfues, and recently developed by Wilsing, that under such circumstances of near approach enormous disturbances of a tidal nature would be set up, amounting it may well be to partial deformation in the case of gaseous bodies, and producing sufficiently great changes of pressure in the interior of the bodies to give rise to enormous eruptions of the hotter matter from within, immensely greater, but similar in kind, to solar eruptions; and accompanied probably by large electrical disturbances.

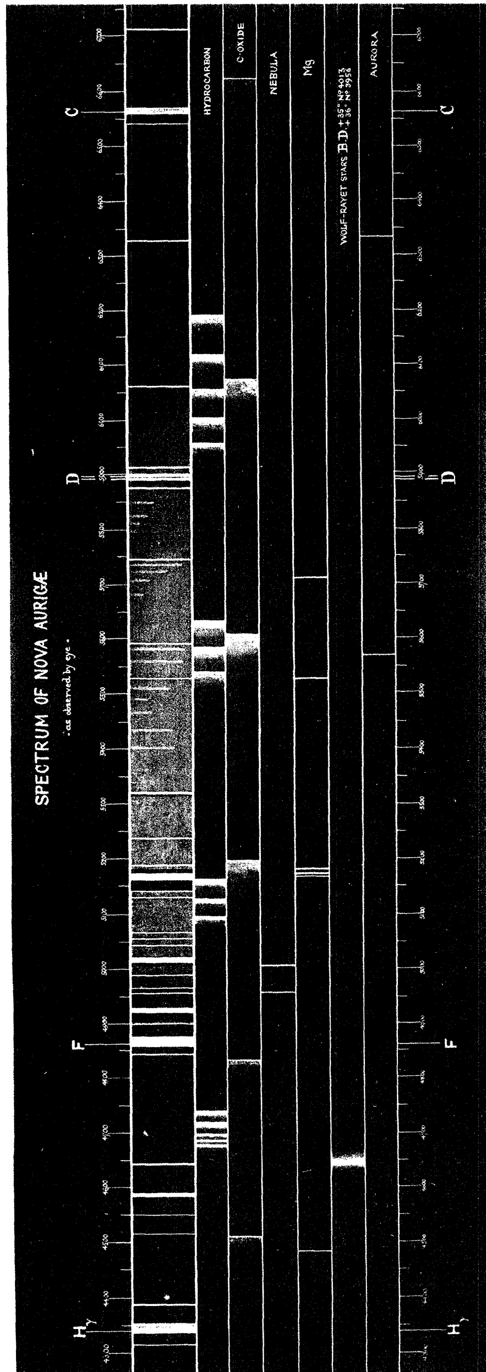
In such a state of things we should have conditions so favourable for the production of reversals undergoing continual change, similar to those exhibited by the bright and dark lines of the Nova, that we could not suppose them to be absent; while the integration of the light from all parts of the disturbed surfaces of the bodies would give breadth to the lines, and might account for the varying inequalities of brightness at the two sides of the lines.

The source of the light of the continuous spectrum, upon which were seen the dark lines of absorption shifted towards the blue, must have remained behind the cooler absorbing gas; indeed, must have formed with it the body which was approaching us, unless we assume that both bodies were moving exactly in the line of sight, or that the absorbing gases were of enormous extent.

The circumstance that the receding body emitted bright lines, while the one approaching us gave a continuous spectrum with broad absorption lines similar to a white star, may, perhaps, be accounted for by the two bodies being in different evolutionary stages, and consequently differing in diffuseness and in temperature. Indeed in the variable star β Lyræ, we have probably a binary system, of which one component gives bright lines, and the other dark lines of absorption. We must, however, assume a similar chemical nature for both bodies, and that they existed under conditions sufficiently similar for equivalent dark and bright lines to appear in their respective spectra.

We have no knowledge of the distance of the Nova, but the assumption is not an improbable one that its distance was of the same order of greatness as that of the Nova of 1876, for which Sir Robert Ball failed to detect any parallax. In this case, the light-





West, Newman, collotyp.

emission suddenly set up, certainly within two days and possibly within a few hours, was probably much greater than that of our Sun; yet within some fifty days after it had been discovered, at the end of January, its light fell to about 1/300th part, and in some three months to nearly the 1/10,000th part. As long as its spectrum could be observed the chief lines remained without material alteration of relative brightness. Under what conditions could we suppose the Sun to cool down sufficiently for its light to decrease to a similar extent in so short a time, and without the incoming of material changes in its spectrum? It is scarcely conceivable that we can have to do with the conversion of gravitational energy into light and heat. On the theory we have ventured to suggest, the rapid calming down, after some swayings to and fro of the tidal disturbances, and the closing in again of the outer and cooler gases, together with the want of transparency which might come in under such circumstances, as the bodies separated, might account reasonably for the very rapid and at first curiously fluctuating waning of the Nova; and also for the observed absence of change in its spectrum.

I may, perhaps, be permitted to remark that the view suggested by Dr. William Allen Miller and myself, in the case of the Nova of 1866,* was essentially similar, in so far as we ascribed it to erupted gases. The great suddenness of the outburst of that star, within a few hours probably, and the rapid waning from the 3·6 magnitude to the 8·1 magnitude in nine days, induced us to throw out the additional suggestion that possibly chemical actions between the erupted gases and the outer atmosphere of the star may have contributed to its sudden and transient splendour; a view which, though not impossible, I should not now, with our present knowledge of the light-changes of stars, be disposed to suggest.

II. "On the Changes produced by Magnetisation in the Length of Iron and other Wires carrying Currents." By SHELFORD BIDWELL, M.A., LL.B., F.R.S. Received April 28, 1892.

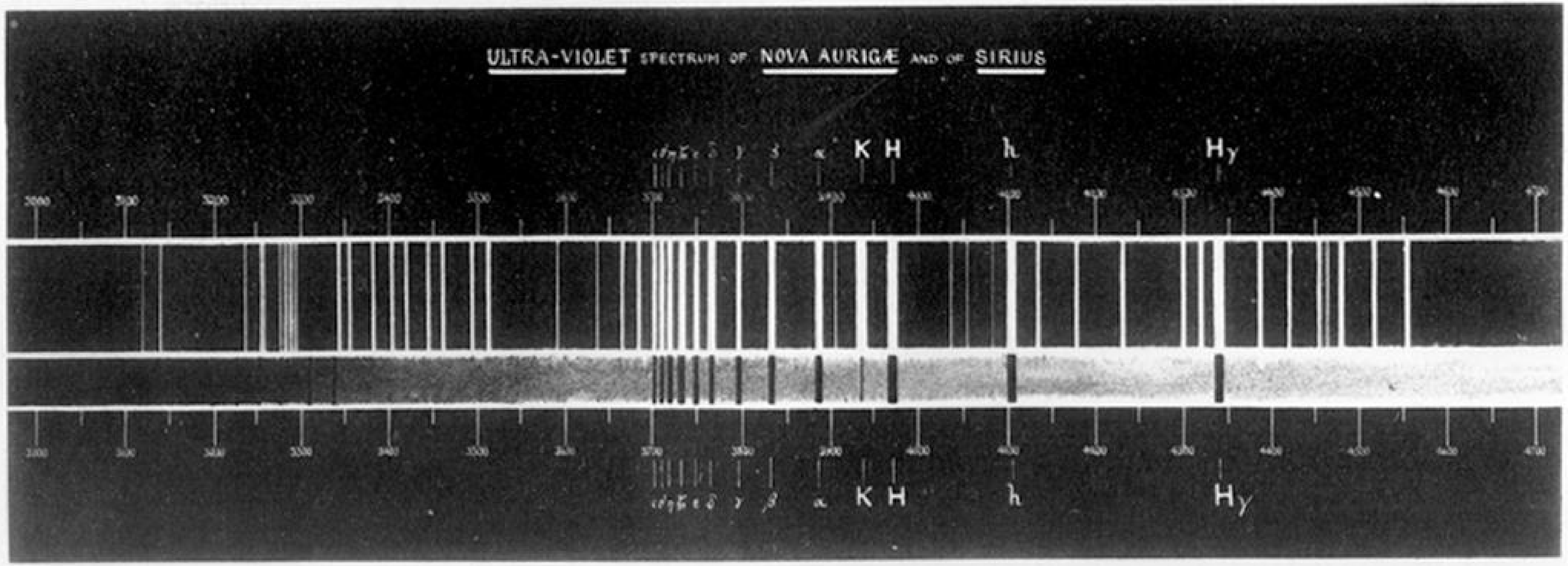
The changes of length attending the magnetisation of rods or wires of iron and other magnetic metals which were first noticed by Joule† in 1841, and have in recent years formed the subject of many experiments by myself,‡ have been found to be related to several other phenomena of magnetism. Maxwell§ has suggested

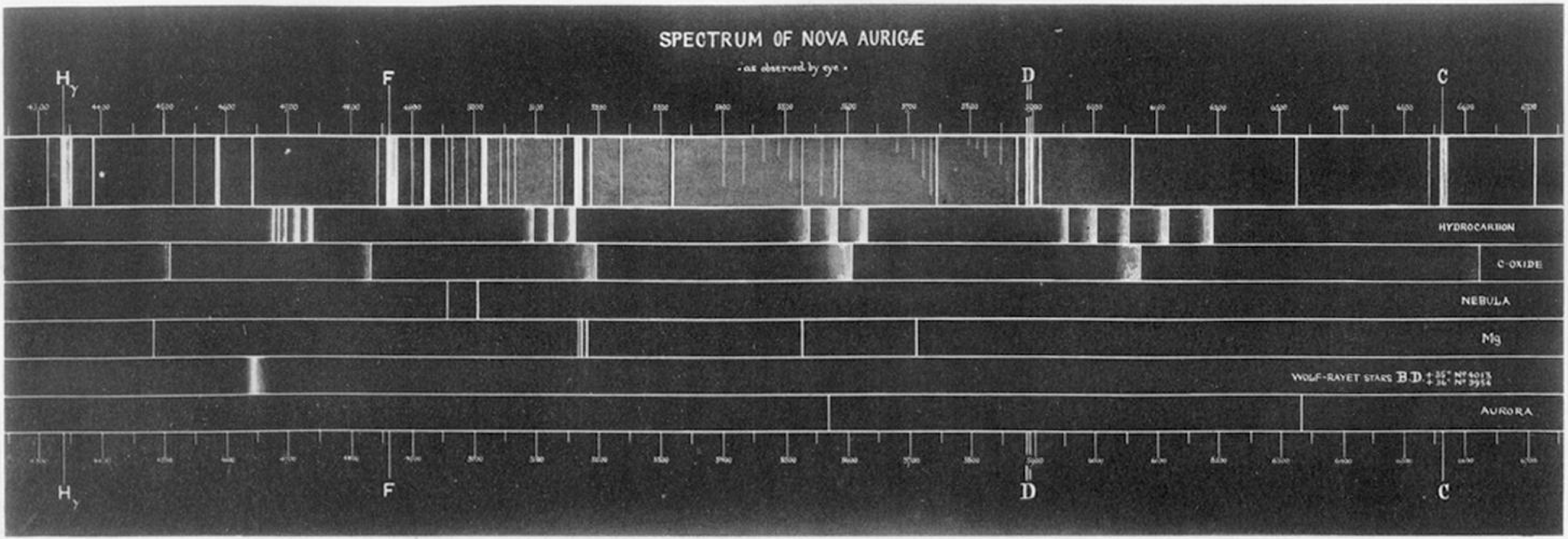
* 'Roy. Soc. Proc.,' vol. 15, p. 146.

† 'Joule's Scientific Papers (Phys. Soc.),' pp. 48, 235.

‡ 'Phil. Trans.,' vol. 179, A, p. 205; 'Roy. Soc. Proc.,' No. 237 (1885), p. 265; No. 242 (1886), p. 109; No. 243 (1886), p. 257; vol. 43, p. 406; vol. 47, p. 469.

§ 'Electricity and Magnetism,' vol. 2, § 448.


ULTRA-VIOLET SPECTRUM OF NOVA AURIGÆ AND OF SIRIUS
K H
h
Hγ
K H
h
Hγ


SPECTRUM OF NOVA AURIGÆ
as observed by eye
Hγ
F
D
C
HYDROCARBON
C-OXIDE
NEBULA
Mg
WOLF-RAYET STARS B.D.
AURORA
Hγ
F
D
C